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THE OMPAT LEVEL I NEUROPHYSIOLOGICAL PERFORMANCE ASSESSMENT BATTERY: NPPAB

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NOTICES

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13. ABSTRACT (Maximum 200 words)

This report presents specifications and methodology for the tests of the Tri-service Neurophysiological Performance Assessment Battery (NPPAB). The NPPAB is designed to evaluate the effects of medical pharmaceuticals on military-relevant human performance. It is intended to serve as an initial screening tool that will identify neurological systems and functions adversely affected by chemical agents. The tests of the NPPAB comprise seven electrophysiological procedures designed to assess the functioning of the visual, auditory, and somatosensory systems, as well as the higher-order processes of selective attention and short-term memory. The tests are:

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CONTENTS

ABSTRACT

The Level I Screen represents the first of three major, interdependent assessment levels in a Tri-service research program that has been designed to evaluate the effects of medical treatment and pretreatment compounds on military-relevant performance. The primary objective of this "first look" at the effects of pharmaceutical compounds on human performance is to identify neurological systems and functions that have been adversely affected by a treatment or pretreatment compound. This information will, in turn, provide guidance for constructing a more in-depth, Level II screen and will yield instrumentation and testing protocols for Level III drug-by-stress interaction and field-test studies.

Many pharmaceuticals that enter military medicine programs have long histories of medical use. Clinical and research information about these compounds exists that is immediately suitable for the design and support of Level II in-depth cognitive and physiological screening efforts. As new pharmaceuticals are developed, however, such information is not likely to be available. To obtain the necessary data expeditiously, the Level I Task Area Group (TAG) of the Office of Military Performance Assessment Technology has undertaken the development of an automated, standardized, and clinically relevant assessment of nervous system integrity. In further phases of our screening program, the Level I data and results will aid in the determination of the type and design of more system-specific (e.g., visual, physiological, or cognitive) assessments of the effects of pharmaceutical compounds on military-relevant performance.

The Level I Screen will include two major subsets of tests: one subset will comprise an automated neuropsychological evaluation and the other will emphasize neurophysiological (primarily evoked-potential) assessment. In addition, a minor subset will consist of selected psychomotor tests. Standards and specifications for the Neurophysiological Performance Assessment Battery (NPPAB) constitute the central focus of this report. These are described on an individual test basis in the following sections.

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1. INTRODUCTION

During the early stages of the Office of Military Performance Assessment Technology (OMPAT) research program, a decision was made to capitalize on the expertise resident in the Level I Task Area Group (TAG) membership and develop a standardized, Tri-service Neurophysiological Performance Assessment Battery (NPPAB). This effort has included development of a network of eight laboratories that will contribute to a common archive during the validation stages of the program. The NPPAB will serve two important functions: an independent human performance and neurotoxicological screen and Level I/II metric that will allow concurrent neurophysiological and cognitive performance assessment. The latter function is designed to complement the Level II Unified Tri-service Cognitive Performance Assessment Battery (UTCPAB) performance data by simultaneously providing relevant neurodiagnostic information.

During the past two decades, a sophisticated methodology and theoretical framework has evolved from research on various measures of sensorially evoked and cognitively elicited electrophysiological responses. This area of technology development and research has produced a well-established set of neurodiagnostic instruments and procedures (e.g., evoked potentials EPs) that are valid and reliable means to determine the functional integrity of the central and peripheral nervous system. Pattern-reversal visual EPs (PREPs), steady-state EPs (SSEPs), brainstem-auditory evoked responses (BAERs), and short-latency somatosensory EPs (SEPs) are among the most well-established indices of function and pathology in their respective sensory systems. These tests form the core of our sensory-EP evaluation, which is designed for rapid assessment of the integrity of sensory systems. Cognitive functions will be assessed by eliciting the P300 and other, established event-related potential waveforms in a variety of paradigms.

The Level I TAG has selected a primary set of nine electrophysiological tests and has standardized the protocols to form the basis of the NPPAB library. These are listed as follows:

1. Steady-state Evoked Potentials (SSEPs)
2. Pattern Reversal Evoked Potentials (PREPs)
3. Brainstem-Auditory Evoked Responses (BAERs)
4. Somatosensory Evoked Potentials (SEPs)
5. Oddball Paradigm (P300 EPs)
6. Sternberg Memory Task
7. Spontaneous Electroencephalogram (EEG) Recording
8. Selective attention task
9. Heartrate

The OMPAT's recommended procedures for administering these tests are outlined in the following chapters.

2. GENERAL METHODS

ELECTRODES

Electrode Reference

Before testing, the researcher must decide whether to use a monopolar or bipolar referencing procedure. Throughout this text, we specify the type of reference to be used with each test. The following is a summary of the issues and rationale underlying the specifications.

When a monopolar reference is chosen, an electrode is placed over a location where electrical activity of interest is expected to occur, and the activity it records is referred to the electrical activity at a second, presumably inactive, location, such as the ear lobe, mastoid process, or sternum. In contrast, a bipolar recording is obtained by referring one active electrode to another. Monopolar reference schemes clearly depict the amplitude-by-time patterns of the signals present at the active electrodes. In contrast, bipolar recordings yield voltage waveforms that are differences between signals simultaneously present at two active electrodes. Monopolar recordings may be more susceptible to electrical artifacts than those obtained with bipolar recordings. Furthermore, the degree to which the commonly used inactive-reference sites are really inactive is a matter of some debate. Finally, a bipolar montage can be particularly good for recording activity localized to relatively small areas of the scalp, whereas widespread activity may be more accurately represented with a monopolar recording scheme (1).

Electrode Selection

The choice of electrodes depends somewhat on the specific recording environment in which EEG data will be collected. In general, however, the electrodes should be fairly small (around 8 mm in diameter) to localize the recording area as much as possible. If the recording montage includes many electrodes, small electrodes will be easier to place than large electrodes. Small electrodes, however, tend to be more susceptible to noise. Silver and silver chloride electrodes are preferable because they do not polarize rapidly. Other types of electrodes, such as gold-plated electrodes, may be used if relatively constant DC offsets caused by polarization are unimportant. All of the electrodes employed in a montage should be constructed of the same material (2).

Electrode Placement

The placement of the recording electrodes depends on the objectives of the recording session. To record activity from visual cortex, for example, active electrodes are placed over the posterior scalp. For consistency and uniformity between recording sessions and among laboratories the International 10-20 system should be used to determine the precise location of each placement (3). The 10-20 system describes procedures for determining the locations of 19 EEG recording sites. Each location is designated by a letter and a number. The letters are F, T, C, P, and O, which correspond to frontal, temporal, central, parietal, and occipital scalp, respectively. The numbers, which serve the functions of subscripts, are odd or even. Odd numbers correspond to recording sites to the left of scalp midline; even numbers correspond to recording sites to the right of midline. Recording sites on the scalp midline are assigned the subscript "z" (for "zenith"). Thus the site P3 designates a location on parietal scalp to the left of midline. The location Fz is on frontal scalp on the midline.

Electrodes should be placed at each site of interest by precisely measuring and marking each electrode position, before a thorough cleaning with alcohol or a special purpose solution. Each electrode site should be scrubbed until the skin turns slightly pink because the impedances between active and reference electrodes must be 5k Ohms or less. Low impedances improve the efficiency of the common mode rejection of electrical interference. Once the site is clean, the electrode is attached to the scalp with tape, electrode paste, and gauze or collodion. If paste will be used as the conduction medium between the scalp and electrode, the paste should be applied before attaching the electrodes. If gel will be used, it may be applied prior to attachment or injected through the small hole present in the tops of some electrodes. An impedance meter should be used to verify that impedances do not exceed 5k Ohms.

An electrode cap can be used to apply a large number of electrodes. These caps frequently contain all of the electrodes specified in the 10-20 placement system; some contain more. The electrodes are generally mounted to elastic fabric that stretches over the subject's scalp and is held in place with a chin strap or body harness. If an electrode cap is used, it should be applied by first determining the circumference of the subject's head, marking a forehead placement site, selecting a cap of the correct size (small, medium, or large), and securing the cap into position. Then, electrode gel is injected into the small hole in the top of each electrode, the scalp is slightly abraded with a blunted syringe needle[1] or the blunt wooden end of a cotton-tipped swab, and impedances are checked. This procedure works well and is much faster than applying each electrode individually. Special care should be taken to ensure that the cap is on straight, that it remains secure throughout testing, and that the electrodes are gelled to the smallest extent required to reduce impedances. Overfilling the electrodes can cause the gel to run and create electrical shorts between recording sites.

Electrode Care

Most EEG electrodes may be reused many times without problems if they are well maintained. Once electrodes are removed from the scalp they should be soaked in hot water to remove any conductive gel or paste and cleaned to remove any residual collodion without removing the gold or silver chloride coating. Once preliminary cleaning is complete, electrodes should be disinfected in a cationic quaternary ammonium agent.

RECORDING EQUIPMENT

Collection of EEG data for visual examination is best performed with a polygraph equipped with preamplifiers and amplifiers capable of following electrical activity that ranges from below 0.5 Hz to about 100 Hz. Polygraph pens, however, cannot accurately follow signals above about 60 Hz. If resolution of higher frequencies is required, a computer equipped with an analog-to-digital converter will be necessary. Prior to recording, the polygraph should always be calibrated to ensure the presence of a proper baseline (0 volts when the pen corresponding to each recording channel is centered) and an accurate sensitivity setting (a known pen excursion in response to a known calibration signal). Follow the procedures described in the manufacturer's operating manual.

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[1]Any blunted needles used to inject electrode gel through the holes in the tops of EEG electrodes and to abrade the subject's scalp should be discarded immediately after use. Under no circumstances, should one of these needles be used on more than one subject.

With increased computer and electronic sophistication, it has become possible to collect, display, store, and analyze data with either general-use computers or specialized EEG and EP recording systems. Some specialized systems provide a wide array of data collection and analysis routines that can automate the quantification of the EEG more than is possible with polygraph pen recordings. Procedures for setting up and running these systems are specified in the manufacturers' documentation. Basically, however, they should permit the examination of spontaneous EEG activity from about 0.5 Hz to about 70-100 Hz. Many long-latency evoked responses can be recorded with the same frequency resolution. Shorter-latency evoked responses typically require higher rates of analog data sampling and different filter settings. These settings are described in the methodological sections of the chapters that follow.

RECORDING PROCEDURE

Testing Environment

A quiet and comfortable testing chamber should be used. It should be equipped with a subject-to-equipment interface, relevant stimulus generating or display devices, and environmental controls. The area should be well ventilated and adequately heated or cooled (i.e, thermoneutral). A camera permitting visual monitoring of the subject and an intercom connecting the equipment station to the testing chamber are both desirable. If the equipment is located in the same room as the subject, care must be taken to eliminate any acoustical noise or visual stimulation from the recording equipment that might interfere with testing.

Subject Preparation and Instructions

Each subject should be thoroughly instructed before each test session to reduce the probability that collected data will be contaminated with movement or muscle artifact. Subjects should be told about the influence of slight movements, talking, and eye blinks and eye movements on the outcome of EEG recordings. Also, subjects should be warned about the type of data contamination that can result from muscle artifact, particularly jaw muscle tension. A brief initial recording should be made to determine the quality of the signal. If problems arise, have the subject perform muscle relaxation exercises (tense and release exercises with deep breathing) to reduce muscle tension. Subjects are often unaware that they are keeping muscles tense. Most subjects are very cooperative and will be happy to help the experimenter.

Subjects who have never been exposed to electrophysiological recording are sometimes anxious during the first few sessions. The experimenter can eliminate much of this anxiety by providing the subject with a detailed explanation of the task, and information concerning the recording equipment, procedures, and the duration of the session.

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3. STEADY-STATE EVOKED POTENTIALS (SSEPs)

TASK DESCRIPTION

The visual SSEP is elicited by presenting a continuously flickering stimulus to a human observer. After a few seconds of stimulation, the brain settles into a steady-state response mode, which has the same frequency as the stimulus but which lags behind the stimulus in time due to the brain's transmission time requirements (1). This lag time, or transmission latency, may be affected by workload, stress, and physiological changes within the brain (see reference 2 for a discussion of demyelinating diseases and their effects on transmission time).

EXPERIMENTAL TEST FACILITY

See chapter 2.

TECHNICAL PARAMETERS

Stimuli

Type:	amplitude-modulated, diffuse white light
Amplitude-by-time waveform:	sum of sinusoids
Frequency composition:	
Low frequency stimulation	8, 9, and 12 Hz
Medium frequency stimulation	14, 17, and 20 Hz
High frequency stimulation	42, 46, and 50 Hz
Intensity (brightness):	
Low and medium frequency	50 fL
High frequency	100 fL
Modulation:	
Low and medium frequency	30%
High frequency	60%
Viewing Distance:	1 m from the subject's nasion
Repetition rate:	epochs of stimulation follow one another without pause
Mode of delivery:	see Other Considerations, below
Stimulus repetitions:	enough to produce 20 artifact-free epochs

EEG Recording

Recording channels:	1 or more
Amplifier gain:	50,000
Lower-cutoff frequency:	0.30 Hz
Upper-cutoff frequency:	300 Hz
EEG sampling rate:	700 Hz or higher
Recording-epoch duration:	2.048 s
Artifact-rejection criterion:	reject epochs containing peak voltages with absolute amplitudes exceeding 50 μV

Electrode Placement

Channel	Recording site	Reference site
1	Oz	A1 and A2 (linked)

Ground: Forehead

PROCEDURE

General

Position the subject in a comfortable chair at eye level with the stimulus generator and 1 m from it. Instruct the subject to focus on the center of the display device and to relax as much as possible. Record the SSEP per specifications. Individuals with corrected vision should wear their glasses during the test procedure.

Instructions to Subjects

This test is called the steady-state evoked response. It is a measure of visual acuity (i.e., how clearly you can see). Please sit comfortably, but restrict eye and other movements, such as blinking or tapping your fingers, and direct gaze toward the center of stimulus generator. Remember, make yourself comfortable and relaxed, but at the same time, try to restrict movements. Listen quietly and attend to the lights during the test.

DATA ANALYSIS

The analysis consists of computing an ensemble average of the cross-spectrum comparison for each paired EEG channel and photo-diode channel. From the resultant complex average, the phase lag is calculated for each of the three stimulating frequencies. With each set of the phase lag values, a straight-line curve fit (linear regression) is calculated. The apparent transmission latency of the brain is then determined to be slope/2. A coherence value is also calculated for each of the stimulating frequencies to be used as a criterion for acceptance of the data. Coherences above 20% are acceptable.

OTHER CONSIDERATIONS

a. The recommended specifications for sampling rate and epoch duration yield 256 digitized voltages per epoch per EEG channel selected (125 voltages/s x 2.048 s = 256 voltages). This simplifies calculating the Fast Fourier Transform of the SSEP waveform.

b. The flickering stimulus should be presented by fluorescent tubes whose intensities are modulated at the specified rates. The actual stimulus output should be recorded using a photo diode. The photo diode response can then be compared to the EEG data when computing coherence and phase lag.

c. The raw EEG data must be filtered before digitizing to avoid aliasing artifacts. A bandpass of 0.03-300 Hz is recommended with a roll-off of less than 12 db per octave.

d. Begin EEG collection after a fixed delay of 10 s relative to the onset of stimulation to allow the brain's EEG response to reach a steady state.

e. Stimulus Frequency Composition. When stimuli are presented at flicker frequencies between 5 and 60 Hz, three frequency ranges produce enhanced amplitude responses in the SSEP. The largest responses are obtained at approximately 10 Hz, the next largest at about 18 Hz, and the third largest around 50 Hz (3). The three frequency ranges specified earlier fall within these three
ranges.

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4. PATTERN REVERSAL EVOKED POTENTIALS (PREP's)

TASK DESCRIPTION

The stimulus in this test is an alternating (reversing) checkerboard pattern. The response of interest is the transient, visually evoked response (VER) produced by each reversal of the pattern. The pattern reversal evoked potential's (PREP's) largest peak, P100, provides an index of visual pathway integrity and can be used as a measure of neuronal conduction velocity within the CNS. An important property of the PREP is that it produces highly reliable latency measurements. Latencies that are more than 9 to 11 ms longer than the average for "normal" subjects generally indicate abnormality (1,2).

EXPERIMENTAL TEST FACILITY

See chapter 2. In addition, moderate background illumination should be provided. We recommend using a red, 25 W lamp located approximately 3 m directly behind the subject's head, at eye level.

TECHNICAL PARAMETERS

Stimuli

Type:	black and white checkerboard pattern
Check sizes:	32 and 64 checks subtending 43 and 21.5 m of arc, respectively, forming 30 x 30 cm checkerboards
Intensity:	50 cd/m^2 mean luminance (approximately 35-40 fL)
Contrast:	50% or greater
Duration:	250 ms
Reversal rate:	1.7 Hz
Background illumination:	see the discussion of the facility above
Stimulus repetitions:	enough to produce at least two sets of 100 artifact free epochs per check size
Viewing distance:	the center of the video screen should be 1 m from the subject's nasion at eye level

EEG Recording

Recording channels:	1 to 4
Amplifier gain:	50,000
Lower-cutoff frequency:	5 Hz
Upper-cutoff frequency:	250 Hz
EEG sampling rate:	700 Hz or higher
Recording epoch duration:	250 ms
Artifact rejection criterion:	reject epochs containing peak voltages with absolute amplitudes exceeding 50 μV

Electrode Placement

Channel	Recording Site	Reference Site
1	Oz	FPz
2	O1	FPz
3	O2	FPz
4	Oz	Cz

Ground: A1

PROCEDURE

General

Position the subject in a comfortable chair at eye level with the stimulus display and 1 m from it. Individuals with corrected vision should wear their glasses during the test procedure. Instruct the subject to fixate on a dot placed at the center of the display and to relax as much as possible. Record the PREP per specifications.

Instructions to Subjects

This test is called the pattern-reversal evoked response. It is a measure of visual function. Please sit comfortably but restrict eye and other movements, such as blinking or tapping your fingers, and direct your gaze toward the center of the TV screen. Focus on the dot in the middle of the screen. Silently count every other alternation of the checkerboard pattern. Remember, make yourself comfortable and relaxed, but at the same time, try to restrict movements.

DATA ANALYSIS

A normative data base should be established in each laboratory for comparison of subject data. The principle datum for amplitude measures is N1-P1 peak-to-peak amplitude (i.e., P100); for latency measures, the principle measure is latency to the major positive component (P100).

OTHER CONSIDERATIONS

a. The calculations yielding the specified check sizes of 21.5 and 43 m of arc are based on checkerboards of 32 and 64 checks per side, respectively (1).

b. This standardized protocol should allow for relative comparison of data that are collected among laboratories. A number of factors can introduce variability in the data. Some sources of variability in PREP responses from normal individuals are:

(1) Age: P100 tends to increase above 50-60 years of age.

(2) Sex: Females tend to have a shorter P100 latency than males.

(3) Normal Variation: 5% of normals display a "W" shaped P100.

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5. BRAINSTEM-AUDITORY EVOKED RESPONSES (BAERs)

TASK DESCRIPTION

This test provides an index of the integrity of the auditory system. It is potentially sensitive to factors affecting the mechanical properties of the ear and to changes in the responses of hair cells, the auditory nerve, and a subset of neurons in the auditory brainstem. The test is carried out by presenting brief sounds to a passive subject while recording the EEG with scalp electrodes. The electrical responses evoked by the sounds are extracted from the EEG by signal averaging (1,2).

EXPERIMENTAL TEST FACILITY

In addition to the aforementioned considerations, the facility should contain a comfortable bed or chaise lounge on which the subject is placed supine during the test. A reclining chair that supports the subject comfortably when all musculature is relaxed can substitute.

TECHNICAL PARAMETERS

Stimuli

Type:	rarefaction clicks
Electrical waveform:	monophasic rectangular
Duration:	0.1 ms (measured as the duration of the electrical waveform applied to the headphones)
Intensity:	65 dB nHL
Repetition rate:	9-11/s
Mode of delivery:	binaural (diotic)
Stimulus repetitions:	enough to produce at least 2000 artifact-free epochs, subdivided into at least 2 separate blocks of epochs

EEG Recording

Recording channels:	1 or more
Amplifier gain:	200,000
Lower cutoff frequency:	10-100 Hz
Upper cutoff frequency:	2.0-3.0 kHz
EEG sampling rate:	12.5 kHz or higher
Recording epoch duration:	at least 15 ms measured from stimulus onset
Artifact-rejection criterion:	reject any epochs that contain peak voltages with absolute amplitudes exceeding 50 μV

Electrode Placement

Binaural Stimulation

Channel	Recording Site	Reference Site
1	Cz	A1

Ground: Forehead

Monaural Stimulation

Channel	Recording Site	Reference Site
1	Cz	Earlobe ipsilateral to ear of stimulation
2	Cz	Earlobe contralateral to ear of stimulation

Ground: Forehead

PROCEDURE

General

Following electrode application, have the subject lie down or sit in a comfortable position. Be sure the subject is relaxed.

Instructions to Subjects

The test you are about to be given is a physiological evaluation of your hearing. The test consists of a rapid sequence of clicks presented over headphones. We will be recording your EEG while the clicks are being presented. You do not have to pay attention to the clicks nor respond to them in any way. The EEG or brainwaves measured in this test are extremely small and any movement can affect the recording process. For this reason, please relax as much as you possibly can during the test. The test should take less than 5 min. During this time, please close your eyes. Please relax your face, neck, and shoulders as much as possible, and try to move as little as possible.

DATA ANALYSIS

a. Nomenclature: Waves I to VIII here refer to the first through eighth, vertex-positive peaks of the human auditory brainstem response (2).

b. Signal-to-noise ratio (S/N): Noise levels should be reported along with amplitudes and latencies. Overall noise levels can be estimated, for example, by the method of Schimmel (3). The approximate S/N of a response peak can be taken as the peak's measured amplitude, relative to the epoch-mean voltage, divided by the estimated, root-mean-squared noise level.

c. Amplitude measurement: The amplitude of each positive-going peak (I-VII) with S/N > 2.0 should be measured relative to the amplitude of the immediately following negative-going peak. Peak measurements with S/Ns < 2.0 should not be reported. With the exception of Wave I, each such peak also should be measured relative to the amplitude of the immediately preceding negative-going peak. Amplitude measurements relative to prestimulus baseline are recommended but not to the exclusion of peak-to-peak measurements.

d. Latency measurement: The latency of each peak (I-VIII) with S/N > 2.0 should be measured relative to the onset of the electrical stimulus applied to the headphones. Measurements of interpeak intervals are frequently of interest and definitely should be reported in studies of factors that could affect neural transmission times. If the headphones used are not TDH-49, the delay between the electrical pulse and the peak of the initial acoustic rarefaction pulse should be measured, using an artificial ear, and should be reported. The latencies of peaks with S/Ns < 2.0 should not be reported.

OTHER CONSIDERATIONS

a. Stimuli are rarefaction clicks generated by applying pulses of the appropriate polarities to the leads of TDH-49 headphones (or headphones with equivalent frequency responses). The voltage polarity required to produce rarefaction pulses should be verified for each headphone by, for example, the method of Durrant (4). In some cases you may want to compare the responses produced by clicks of opposite polarity. We do not recommend canceling stimulus artifacts and the cochlear microphonic by averaging responses to stimuli of alternating polarity because the latencies of responses to stimuli of opposite polarities differ.

b. Stimulus intensity should be determined in the laboratory where testing will take place to account for the effects of variation in equipment and acoustic background noise. Decibels nHL refers to the intensity of a sound measured in dB, relative to the average of the behavioral thresholds of a group of n normal-hearing listeners. When determining thresholds, use the same equipment, stimuli, and stimulus repetition rate used in testing.

c. Avoid using stimulus repetition rates with reciprocals equal to integer multiples of the period of the local AC line frequency.

d. Diotic stimulation can be helpful when EEG noise levels are high or recording time is limited. This is because the signal-to-noise ratios of diotic responses are substantially higher than those of monaural responses. (Diotic stimuli are binaural stimuli that do not differ from left to right ear; *dichotic* stimuli are binaural stimuli that differ between the ears.) Note, however, that binaural stimulation will tend to cause the electrical cancellation of some BAER peaks with latencies shorter than that of Wave V. Hence, if the purpose of the experiment requires measurements of the earliest BAER peaks, monaural stimuli should be used. Furthermore, only monaural stimuli should be used when testing for neurological disease because many such conditions are unilateral (5). When stimulating monaurally, continuous, white noise should be presented to the nonstimulated ear at an intensity 30 dB below that of the clicks to prevent cross-hearing.

e. Reference electrodes should be placed on the medial sides of earlobes to minimize electrical artifacts (5).

f. The range of lower-cutoff frequencies specified is suitable for recording when EEG noise levels are fairly high. That range is recommended when consistently low noise levels cannot be assured or when recording times are limited. When noise levels are low, a lower-cutoff frequency in the range of 0.02-0.03 kHz is preferable (6).

REFERENCES

1. Jewett, D. L., Romano, M. N., and Williston, J. S., "Human Auditory Evoked Potentials: Possible Brainstem Components Detected on the Scalp." Science, Vol. 167, pp. 1517-1518, 1970.

2. Picton, T. W., Hillyard, S. A., Krausz, H. I., and Galambos, R., "Human Auditory Evoked Potentials. I. Evaluation of Components." Electroencephalography and Clinical Neurophysiology, Vol. 36, pp. 179-190, 1974.

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6. American Electroencephalographic Society, "Guidelines for Clinical Evoked Potential Studies." Journal of Clinical Neurophysiology, Vol. 1, pp. 3-53, 1984.

6. SOMATOSENSORY EVOKED RESPONSES (SEPs)

TASK DESCRIPTION

This procedure provides an index of the integrity of the afferent somatosensory nervous system from median nerve to somatosensory cortex (1,2). In the test described here, brief electrical pulses are administered transcutaneously to the median nerve at one wrist. Evoked potentials elicited by the stimuli are recorded from Erbs point and the scalp surface over the contralateral somatosensory cortex. Signal averaging is used to extract stimulus-related activity from the background noise.

EXPERIMENTAL TEST FACILITY

See chapter 2.

TECHNICAL PARAMETERS

Stimuli

Type:	constant current electrical pulse
Electrical waveform:	monophasic rectangular
Duration:	See General Procedures below
Intensity:	See General Procedures below
Repetition rate:	5.1/s
Mode of delivery:	bipolar
Stimulus repetitions:	enough to produce at least 1000, artifact-free epochs, subdivided into at least two, separate blocks of epochs
Stimulus electrodes:	See General Procedures below

EEG Recording

Recording channels:	2 or more
Amplifier gain:	50,000
Lower-cutoff frequency:	20 Hz
Upper-cutoff frequency:	3 kHz
EEG sampling rate:	6 kHz or higher
Recording epoch duration:	at least 40 ms measured from stimulus onset
Artifact-rejection criterion:	reject epochs containing peak voltages with absolute amplitudes exceeding 50 μV

Electrode Placement

Channel	Recording Site	Reference Site
1	Erbs Point	FP2
2	Cervical 7 (C3)	FP2
3	Cz	Opposite hand or arm

Ground: Forehead

PROCEDURE

General

Preparation of the skin surface where electrodes are to be placed should include scrubbing the skin with an abrading compound (e.g., Omni Prep). The stimulating electrodes should be placed on the right median nerve, 2 cm above the wrist crease. The distance between electrodes should be 2-3 cm, with the anode (+) electrode placed distally and the cathode (-) electrode placed proximally. We recommend placing the cathode on one side of the arm and the anode on the opposite side to prevent current leakage between electrodes. The ground electrode should be located on the palmar surface of the forearm proximal to the cathode. We recommend using a plate or band electrode as the grounding electrode.

The electrical stimulus should be a 0.1-ms, constant-current pulse delivered at a rate of 5.1/s. The stimulus must be generated by a constant current source because electrical stimulation reduces skin resistance. If a constant-voltage source were used, the current applied would increase as the resistance decreases. The intensity of the stimulus should be adjusted so that each pulse produces a thumb twitch. If the stimulating electrodes are properly applied, this intensity should be approximately 7-8 mA. The pulses should NOT be painful.

Instructions to Subjects

The test you are about to take is a rapid electrophysiological evaluation of your sense of touch. Rather than using touch stimuli, we will use brief, mild electrical pulses to your wrist. We will adjust the electrical stimuli to a level that will make your thumb twitch. This may be annoying; however, it will not be painful. Your EEG will be recorded as the pulses are delivered. While we are recording your EEG, it is important that you relax and refrain from moving around in the chair. Movements and muscle tension will interfere with the EEG recording and will prolong the test session. If at any time the shock seems too strong, raise your left hand or remove the electrodes.

DATA ANALYSIS

The major somatosensory response components are designated as follows: P10, P12, P14, N19, P20, and P23, where 'P' indicates the positive polarity of the response peak, and the subsequent number indicates the approximate latency of the peak in ms.

OTHER CONSIDERATIONS

We recommend allowing the subject to adjust the stimulus intensity. This often tends to reduce anxiety associated with electrical stimulation.

REFERENCES

1. Cracco, R. Q. and Cracco, J. B., "Somatosensory Evoked Potentials in Man: Far Field Potentials." Electroencephalography and Clinical Neurophysiology, Vol. 41, pp. 460-466, 1976.

2. Tsuji, S., Shibasaki, H., Kato, M., Kuroiwa, Y., and Shima, F., "Subcortical Thalamic and Cortical Somatosensory Evoked Potentials to Median Nerve Stimulation." Electroencephalography and Clinical Neurophysiology, Vol. 59, pp. 465-476, 1984.

7. AUDITORY P300 ODDBALL TASK

TASK DESCRIPTION

The oddball task was one of the first paradigms used in studies of the P300 event-related potential ERP. It remains the most widely employed and most completely characterized of all ERP paradigms. In the auditory version of this task, the subject listens to a series of tones that are designated as "rare" or "frequent." The rare tones are presented 20% of the time and differ in pitch from the frequent tones. The subject is instructed to attend to (count) the rare tones and to ignore the frequent tones. The EEG responses elicited by the tones are sorted according to stimulus type (rare or frequent) and then averaged separately.

The averaged, evoked response elicited by the rare tones contains a primary positive wave (P300) that peaks, in this task, about 250-400 ms after the onset of the tone. The response elicited by the frequent tones usually contains little or no P300 activity. The general consensus is that P300 is not a unitary phenomenon but the composite of several, overlapping waves generated by anatomically distinct populations of neurons (1,2). Nevertheless, global measurements of P300 wave latencies and amplitudes are demonstrably associated with factors that affect the process of stimulus evaluation.

EXPERIMENTAL TEST FACILITY

See chapter 2.

TECHNICAL PARAMETERS

Stimuli

Type:	tone bursts
Electrical waveform:	gated sinusoids
Duration:	50 ms
Onset/offset ramps:	linear, 9-ms duration
Intensity:	65 dB nHL
Repetition rate:	1 Hz
Mode of delivery:	binaural
Frequencies:	
Rare tone	1000 Hz
Frequent tone	2000 Hz
Order of presentation:	random (Bernoulli) sequence
Stimulus probabilities:	
Rare tone:	20% of all tones
Frequent tone:	80% of all tones
Stimulus repetitions:	see General Procedure below
Delivery system:	TDH-39 headphones (or the equivalent)

EEG Recording

Recording channels:	4
EEG amplifier gain:	35,000
EOG amplifier gain:	3500
Lower-cutoff frequency:	0.5 Hz
Upper-cutoff frequency:	30 Hz
EEG-sampling rate:	100 Hz or higher
Recording-epoch duration:	1000 ms
Artifact-rejection criterion:	reject epochs containing peak voltages with absolute amplitudes exceeding 50 μV or epochs containing eyeblink deflections exceeding 10 μV

Electrode Placement

Channel	Recording Site	Reference Site
1	Fz	A1
2	Cz	A1
3	Pz	A1
4	EOG (See General Procedure below)	

Ground: Forehead

PROCEDURE

General

As indicated above, the EEG is recorded from Fz, Cz, and Pz, referred to an earlobe. The EOG is recorded from above and medial to the left eye, and referred to the lateral side of that eye. The EEG should be sampled during intervals beginning 150 before stimulus onset and ending 850 ms following stimulus onset. Presentation of the tones should be one-at-a-time and in random order as indicated above. Two hundred artifact-free trials, including a minimum of 35 rare-event trials, must be collected per test session.

Instructions to Subjects

The task you are about to perform evaluates how well you can detect a rare tone in a sequence of frequent tones. You will hear some low-pitched "rare" tones and some high-pitched "frequent" tones. Please listen carefully to the following tones and see if you can tell them apart (play a sequence of 100 low and high tones). Your task will be to attend to and mentally count the low-pitched tones. Ignore the high-pitched frequent tones. We will play the sequence of tones for about 5 min. At the end of the series, you will be asked to report the number of low-pitched tones you counted. We will tell you whether you were correct. While you are listening to the tones, we will record your EEG, that is brainwaves. It is important that you relax, do not move around in the chair, and keep your eyes open and steady. Moving your body or your eyes will cause artifacts in your EEG. We can only use an EEG without artifacts. Since the task will take about 5 min, most people can relax and not move around for this short period. Keeping your eyes open and steady for this period may take some effort. Try to focus your eyes on your hands, knees, or on something low in the room. Move your point of focus every several minutes if you need to. If you must blink, do so vigorously all at once. Remember to count only the low-pitched, rare tones.

DATA ANALYSIS

Analysis typically will focus on amplitude and latency of the P300 component elicited by the rare tones.

REFERENCES

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8. STERNBERG MEMORY TASK (VISUAL)

TASK DESCRIPTION

In this task, evoked responses are elicited by the visual presentation of letters of the alphabet. These letters are divided into two categories referred to as "positive" and "negative" character sets. The positive set is presented for the subject to memorize before presentation of "probe-test" letters. The negative set consists of all other letters in the alphabet. The task is to identify whether each letter presented is a member of the memorized character set (a positive stimulus) or is a nonmember of the memorized set (a negative stimulus). Subjects respond by pressing one of two response keys with the index finger of their preferred hand. Behavioral reaction times to the positive and negative stimuli are recorded along with the EEG. The EEG response, especially a late positive component (P300), is of greater amplitude when the letter presented is a member of the positive set. Its amplitude is attenuated when the stimulus is from the negative set. Both behavioral reaction times and latencies of P300 responses have been shown to vary with the size of the positive character set. Reaction times to positive set letters are faster than those of the negative set (1). Reaction times and latencies of the P300 increase for both positive and negative sets when the number of letters in the positive set is increased.

EXPERIMENTAL TEST FACILITY

See chapter 2.

TECHNICAL PARAMETERS

Stimuli

Stimulus character:	the letters (A-Z)	
Memory set (M-set) sizes:	2, 4, & 6	
M-set presentation time:	30 s/trial	
Probe-item presentation rate:	one every 2 s	
Number of stimuli/set size:	50	
Stimulus probability:		
	positive stimulus	50%
	negative stimulus	50%
Stimulus duration:	600 ms	
Interstimulus intervals:	2000 ms, measured from stimulus onset to stimulus onset.	

EEG Recording

Same as P300 Task; see chapter 7.

Electrode Placement

Same as P300 Task; see chapter 7.

General

The subject is required to press one of two response keys designated positive and negative. Only the preferred hand is used, and the index finger is used tc respond to positive-set test probes. One complete practice session should be conducted before formal testing.

Instructions to Subjects

During this test, you will be presented with a memory set of letters, which will constitute the positive set. After you memorize the positive set, a series of probe letters will be displayed on the screen, one at a time. If the probe letter is one that was part of the positive set (that you just memorized), then respond by pressing the positive response key with the index finger of your preferred hand. When a letter is presented that is not in the positive memory set, then press the negative response key with the same finger.

DATA ANALYSIS

The reaction-time data (in ms) are computed from onset of the stimulus to the time of the manual response. The EEG should be averaged separately for positive and negative stimuli, respectively. As with the Auditory P300 task, the primary component is a large positive wave (P3) that occurs between 250 and 700 ms.

OTHER CONSIDERATIONS

A video monitor screen is required for visual presentation. The same monitor used for the PREP is recommended.

REFERENCES

1. Gomer, F. E., Spicuzza, R. L., and O'Donnell, R. D., "Evoked potential Correlates of Visual Item Recognition During Memory-scanning Tasks." Physiological Psychology, Vol. 4, pp. 61-65, 1976.

9. SPONTANEOUS EEG RECORDING

TASK DESCRIPTION

Spontaneous EEG recordings, subjected to readily available, computer-assisted analyses, enable one to assess pharmacodynamic, pharmacokinetic, and toxicologic properties of drugs (1). Such measures and their correlations with vigilance and performance are useful in describing the characteristics of drugs in the Level I screen. The EEG is sampled concurrently at four scalp locations for 3-min periods while the subject sits in a reclining chair.

EXPERIMENTAL TEST FACILITY

See chapter 2.

TECHNICAL PARAMETERS

Stimuli

None, this is a passive EEG recording procedure.

EEG Recording

Lower-frequency cutoff: 1 Hz
Upper-frequency cutoff: 30 Hz

Electrode Placement

Channel	Recording Site	Reference Site
1	Fz	A1 and A2 (linked)
2	C3	A1 and A2 (linked)
3	C4	A1 and A2 (linked)
4	Pz	A1 and A2 (linked)

Ground: Forehead

PROCEDURE

General

Following electrode application, the subject is asked to sit and relax. The subject should be told that this test has no stimuli and that it entails only passive recording of brainwaves. Four sessions lasting 3 min each are to be recorded. The first should be with the subject's eyes closed while he or she simply relaxes and does nothing. The second session should be recorded with the subject relaxing and doing nothing with eyes open. The subject should, however, be instructed to focus his or her eyes straight-ahead on some object. The third and fourth sessions should be recorded in the same fashion as the previous two. In these runs, however, the subject is asked to engage in mental arithmetic. Sequential subtraction is recommended. Its difficulty should be adjusted to the subject's ability level so that the task is slightly taxing.

Instructions to Subjects

These tests will measure your brain waves during 3 min sessions as you relax. Instructions for the first session: Close your eyes and relax. Instructions for the second session: Open your eyes and relax. Instructions for the third session: Close your eyes and count backward from [e.g., 937] by [e.g., 7s]. Instructions for the fourth session: Open your eyes and count

backward from [e.g., 725] by [e.g., 7s]. If you lose your place as you count backward (or if you reach zero), go back to the beginning and continue.

OTHER CONSIDERATIONS

The EOG should be recorded along with the EEG. The procedure for this should be the same as that described for the Auditory P300 task.

REFERENCES

1. Kellaway, P. and I. Petersen (Eds.), Automation of Clinical Electroencephalography, Raven Press, New York, NY, 1973.

10. SELECTIVE ATTENTION TASK

TASK DESCRIPTION

This paradigm produces a slow negative wave (N_D) that appears to be related to selective attention (1). Four different tones are presented to the subject. Two of the four tones are of one pitch and the other two are of another pitch. For a given pitch, one of the tones is of short duration and the other is long. The short-duration tone occurs on 20% of the trials for each frequency. The subject responds to the short tone of only one frequency. The EEG is collected and averaged separately for each of the four tones. The N_D wave is obtained by subtracting the averaged response to the short tone of the ignored frequency from the averaged response to the short tone of the attended frequency.

EXPERIMENTAL TESTING FACILITY

See chapter 2.

TECHNICAL PARAMETERS

Stimuli

Frequencies:	
Tone 1	1000 Hz
Tone 2	2000 Hz
Tone intensities:	60 dB nHL
Tone durations	50 ms and 100 ms (with 9-ms rise/fall times)
Stimulus presentation rate:	0.67 Hz
Tone probabilities:	100 ms - 1000 Hz (40%) 50 ms - 1000 Hz (10%) 100 ms - 2000 Hz (40%) 50 ms - 2000 Hz (10%)
Designated target stimulus:	50 ms - 1000 Hz tone
Number of trials:	300
Delivery system:	TDH-39 headphones (or the equivalent)

EEG Recording

Same as P300 Task. See chapter 7, with the following exceptions.

Low-frequency cutoff:	0.5 Hz
High-frequency cutoff:	40 Hz
Digitizing Rate:	200 Hz

Electrode Placement

Channel	Recording Site	Reference Site
1	FZ	A1 and A2 (linked)
2	CZ	A1 and A2 (linked)
3	PZ	A1 and A2 (linked)
4	EOG	(recorded as described for the Auditory P300 task.)

Ground: Forehead

PROCEDURE

General

The EEG is recorded from at least 50 ms before tone onset to at least 450 ms after tone onset. Tones are presented binaurally.

Instructions to Subjects

The task you are about to perform evaluates how well you can pay attention to, and detect, certain stimuli (targets) when several different stimuli are presented to you. We are going to present you with four different tones: a long low-pitched tone, a short low-pitched tone, a long high-pitched tone, and a short high-pitched tone. Please listen carefully to a series of these tones and see if you can tell them apart. (Play a series of 100 tones.) Can you tell them apart? Did you notice that the short tones did not occur as often as the long ones? Your job will be to count (press this button when you hear) the low-pitched short tones. To make sure you understand, we would like to let you practice. (Play a series of 200 tones. If the subject was counting the targets, ask for a count at the end. If the subject was pressing the pushbutton, verify that he or she was correct. If the subject was not correct, clarify the problem and rerun the practice as necessary.)

Now we are going to test you while we record your EEG. It is important that you relax; do not move around in the chair and keep your eyes open and steady. Moving your eyes or your body will cause artifacts in your EEG. We can only use EEG without artifacts. The task will take about 5 min. Most people can relax and not move around in the chair for this short time. Keeping your eyes open and steady for this period may take some effort. Try to focus your eyes on your hands, knees, or something low in the room. Move your point of focus every several minutes if you need to. If you must blink, do so vigorously all at once. Also, try your best to detect all the short low-pitched tones.

DATA ANALYSIS

As stated in the task description, the primary component of interest is the slow negative wave designated as Nd. The Nd is obtained by subtracting the averaged response to the short tone of the ignored frequency from the averaged response associated with the short tone of the attended frequency.

REFERENCES

1. Hansen, J. C. and Hillyard, S. A., "Endogenous Brain Potentials Associated with Selective Auditory Attention." Electroencephalography and Clinical Neurophysiology, Vol. 49, pp. 277-290, 1980.

11. HEARTRATE

TASK DESCRIPTION

An electrocardiogram (EKG) is a recording of the electrical activity of the heart, taken from potential (voltage) differences between electrodes attached to the skin of the chest. The variability of the electrical waves (the T and R waves) of the heart have been shown to be related to stress and workload. As a general rule, variability decreases as workload increases, but great stress (such as high g-stress) will cause larger variability. Further, physiological changes in the body caused by other stressors also have been found to influence heartrate (1,2).

EXPERIMENTAL TEST FACILITY

See chapter 2.

TECHNICAL PARAMETERS

RECORDING

Low-cutoff frequency	10-100 Hz
High-cutoff frequency	2000 Hz

ELECTRODE PLACEMENT

Electrodes are usually placed on the suprasternale (uppermost point of the breastbone) and on the lateral side of the trunk, under the last rib of the ribcage (under the arm).

PROCEDURE AND INSTRUCTIONS FOR THE SUBJECTS

Data are sampled every 5 msec, continuously, for an experimenter-determined number of trials. No special equipment is worn, apart from electrodes, and no task is required for heartrate collection. The subject is required to keep body movement to a minimum, to reduce unwanted muscle potential artifacts.

DATA ANALYSIS

The array of interbeat intervals is used to compute the mean beat per minute, variance, and standard deviation of the subject's heartrate apart from electrodes during the trial.

If a measured interbeat interval is more than 2 s or less than 0.4 s, it is not considered a valid interval and is rejected. If the heartrate signal remains above one standard deviation of the mean voltage for more than 180 msec, that section of data is also rejected.

REFERENCES

1. Schyndel, M. Demey, H., and Naring, G., "Cardiovascular responses and problem solving efficiency: Their relationship as a function of task difficulty." Biological Psychology, Vol. 20, pp. 51-65.

2. Wierwille, W. W., "Physiological Measures of Aircrew Mental Workload." Human Factors, Vol. 21, pp. 575-593, 1979.

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